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AUTHOR Baker, Patti R.; And Others
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ABSTRACT

A study was conducted to investigate the comprehensibility of microcomputer-generated color graphics that are displayed on monochromatic monitors. Subjects were 64 second, third, and fourth graders who were randomly assigned to one of two conditions. Children in the first treatment were asked to identify, on a monochrome monitor, a figure that was initially presented in its original form and then as a redesigned, more distinguishable figure with greater figure/ground contrast created by substituting colors that utilized pixel patterns to provide contrast in the monochromatic display. The order of picture presentation was reversed for the children in the second treatment. Analysis of variance showed a significant main effect for the treatment variable: subjects in Treatment II recognized the figure more frequently than subjects in Treatment I. Results indicate that: (1) microcomputer-generated graphics intended for color presentation but displayed on monochromatic monitors may not have sufficient figure/ground contrast; (2) insufficient figure/ground contrast may adversely affect picture comprehension; and (3) younger children, at least through fourth grade, seem to lack the necessary perceptual maturity to overcome the effects of poorly discernible figures on a monochromatic green screen. A list of references and three data tables complete the document. (JB)

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THE DISPLAY OF COLOR GRAPHICS ON MONOCHROME MONITORS: A CONCERN FOR DESIGNERS AND AN OPPORTUNITY FOR RESEARCHERS

Patti R. Baker, John C. Belland, and Marjorie A. Cambre

The Ohio State University

236 Ramseyer Hall

29 West Woodruff Avenue

Columbus, OH 43210

(614) 422-4872

IR012184

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ABSTRACT

This paper presents the problem of displaying color graphics on monochrome monitors, design rules for such graphic displays, and current and proposed research to examine the perceptual and cognitive effects of pictures displayed via monochrome monitors. In order to empirically test the usefulness of the proposed design principles, a study was conducted to examine whether children could recognize computer generated pictures on monochrome monitors. Subjects were 64 second, third, and fourth graders who were randomly assigned to one of two conditions. Children in the first treatment were asked to identify, on a monochrome monitor, a figure that was initially presented in its original form and then as a redesigned, more distinguishable figure. The redesigned figure had greater figure/ground contrast because color substitutions were made that utilized pixel patterns to provide contrast in the monochromatic display. The order of picture presentation was reversed for the children in the second treatment. Results indicated that regardless of grade or FI/FD characteristics, children in this study were unable to discern critical features of a color graphic displayed on a monochromatic monitor unless it was designed to enhance figure/ground separation ($p<.0001$). Implications for further research, as suggested by the results of the study, are discussed.

THE DISPLAY OF COLOR GRAPHICS ON MONOCHROME MONITORS: A CONCERN FOR DESIGNERS AND AN OPPORTUNITY FOR RESEARCHERS

The proliferation of microcomputer generated graphics in instructional software forces new attention upon the issues involved in picture comprehension. Visual learning via computer encompasses several elements: the learner's perceptual system, the design of the visual message, and the medium's manner of conveying that message. While designers and producers can feel confident that pictures will usually enhance their messages, they have less information to assist them in determining the characteristics of pictures that make them more or less appropriate for specific audiences. Furthermore, in the case of computer generated pictures, the designer does not have any control over the hardware used for display.

A critical design issue emerges when graphics intended for color display are presented on monochrome monitors or TV receivers. Color graphics that were designed to be appealing and useful to instruction are found to be less than helpful as monochromatic pictures; figure/ground separation that is aided by color differences is lost in monochrome pictures. Shapes are indiscernible and figures blend into the background.

A SOLUTION FOR THE DESIGN OF PICTURES FOR COLOR AND MONOCHROME DISPLAY

By following design rules developed by Baker (1983), it is possible to design computer graphics that are perceptually salient for both monochrome and color display. These rules, developed for Apple II graphics, are outlined in Table I. The rules suggest which colors can be juxtaposed in order to allow for good figure/ground separation. Because of the way monitors translate the display signal to the screen, Apple II colors are presented on a monochromatic monitor in patterns of pixels (lighted dots). By consulting Table I, the designer can choose which colors can be juxtaposed. The designer can utilize the differing pixel patterns to provide contrast and to avoid similar patterns that weaken figure/ground separation.

Insert Table 1 about here

Although these rules apply specifically to Apple II low resolution colors, the principles generally apply to the design of pictures for other computers also. The computer may not translate display signals into pixel patterns, but colors may appear as shades of gray (or whatever the color of display is.) The designer then applies the general rule: in order to make the picture interpretable in either mode, be sure that juxtapositioned colors exhibit contrasting shades of gray in monochrome. Regardless of the computer or the display hardware, the designer is asked to be sensitive to the range of possible display hardware for color graphics in computer courseware.

THE STUDY

The design rules eminated from the practical notion of making color graphics in computer courseware suitable for the many monochrome monitors in use in schools. Yet there was little empirical evidence that following such design rules would result in pictures that were more intelligible to the children who were the intended users of the courseware. Related research was investigated, and a study was designed to empirically test the design rules that were intuitively needed and purposely formulated. This study is reported in detail by Baker, Belland, and Cambre (1985).

Review of Related Research

Several theoretical and applied areas provide insights into the variables affecting picture comprehension. These include perceptual and developmental psychology, message design, and individual differences within cognitive psychology.

Developmentalists and perceptual psychologists identify experience and maturation as important components of visual perception. A number of researchers have found that age interacts with children's ability to extract relevant information from pictures. Children do not interpret pictures in the same manner as adults nor do they obtain as much information (Campbell, 1981). For instance, young children are unable to ignore irrelevant information and are easily distracted from essential cues by peripheral details (Collins, 1970; Dwyer, 1978; Fleming & Levie, 1978). Younger children have been shown to prefer simpler pictures and to be able to extract more relevant information from them than from more complex pictures (Travers & Alvarado, 1970).

Gardner, Wolf & Smith (1975) further observed that young children's diffuse scanning patterns and numerous small eye movements affect their ability to examine a picture holistically. Travers & Alvarado (1970) suggest that children tend to perceive parts before they perceive wholes. Children in the lower elementary grades are therefore likely to have difficulty perceiving and interrelating the various elements of a picture. Older children are better able to perceive and describe an entire scene.

Gibson (1969:77) posits that experience provides essential practice in detection, discrimination, recognition, and identification; "...as perception develops the organism comes to detect properties of stimulation not previously detected even though they may have been present. With growth and continued exposure to the world of stimulation, perception becomes better differentiated and more precise."

In addition to the issues of developmental visual perception, critical features of pictures such as figure/ground are also important to picture comprehension. Figure/ground is so basic a concern in message design that it is usually taken as the starting point of form comprehension. A German researcher named Rubin is credited with the

first studies of the features of figure/ground organization in 1921 (cf Haber & Hershenson, 1973:184). He observed that the figure has form or shape, with recognizable "thinglike" qualities, whereas ground is either formless or having weaker or less definite form characteristics. When figure/ground relationships break down, the result is camouflage or lack of meaning.

Contour is a critical element that separates figure from ground, although the contour usually seems to belong to the figure. Information or uncertainty is concentrated along contours or edges. Thus, if the contours are not perceived as edges of the figures, the figures are difficult to see. Hochberg (1962:39) recommends the addition of cues to enhance figure/ground separation and make the edges more discernable; among them are making the figure more realistic or iconic, using pigment or other drawing to simulate shade and shadows, using depth or perspective techniques.

The need for discernible edges of objects is as important in animated pictures as in still pictures. In a discussion of perceptual precepts of animations intended to facilitate learning for children, Caldwell (1978:23) suggests that children 4-8 years old will more readily perceive drawn objects if they are "outlined with obvious, unbroken boundaries than when the boundaries are broken or otherwise indistinct." She further suggests that bright or well-illuminated objects will be discriminated as the figure first.

Dwyer (1978) found that individual differences such as intelligence, reading comprehension, and entry behavior are critical variables in students' ability to learn from different types of pictures. Cognitive style might also be a differentiating variable in children's ability to extract information from pictures. Field independent persons evidence the ability to experience items as discrete from their background and to overcome embeddedness (Ausburn & Ausburn, 1978). Furthermore, the field independent person is likely to seek differentiating information with well distinguished parts, while the field dependent person is more likely to have "fused" experiences, and be unable to separate items of information from their contexts (Guilford, 1980). For the field independent person, sufficient figure/ground separation in a picture becomes even more important.

The Current Study

Perceptual development, message design, and individual differences provided the framework for the present study. A computer-generated picture of a unicorn which was provided as a reward picture in a commercially-developed courseware package was extracted so that it could be displayed independently. In this original version, a critical attribute of unicorns, the singular horn, was barely distinguishable from the the background when displayed on a monochromatic monitor. Another picture was constructed with precisely the same form and content but following Baker's rules. Consulting the table revealed that substitution of two colors was required. The redesigned picture portrayed a unicorn which looked the same as the original picture on a

color monitor but had an easily distinguishable horn on a monochromatic monitor. These pictures were displayed on monochromatic monitors to subjects who were asked to describe the content of the pictures. Previous to administering the treatments, the luminescence of the screens was measured and adjusted equally on the monitors so contrast and brightness would not affect results.

Hypotheses

The following hypotheses guided the design and interpretation of the study:

H_1: Subjects will name the main figure in the picture correctly after they experience the redesigned picture. That is, subjects in the first treatment condition will respond correctly on the second trial and subjects in the second treatment condition will respond correctly on the first trial.

H_2: Subjects who experienced the second treatment will be able to name the main figure correctly on both trials.

H_3: Subjects who are field independent will name the main figure correctly more frequently under either treatment condition.

H_4: Subjects from higher grades will name the main figure correctly more frequently under either treatment condition.

Design

Subjects were drawn from the second, third and fourth grade classes of an urban elementary school. Within each grade level, subjects were randomly assigned to one of two treatments. In the first treatment, subjects were shown first the original reward picture on a green-screen (monochrome) monitor and asked to name what they saw. After each subject had made a response, he/she was asked what else was seen. Then the subject was shown the redesigned picture and asked the same questions. In the second treatment, subjects were shown the pictures in the reverse order; the redesigned picture was shown first and the original picture shown second. It was assumed that the identification of the unicorn in least one of the versions indicated that the subject was familiar with the concept "unicorn." Only four of the subjects did not recognize the unicorn in either version.

In another data-gathering session approximately a week later, subjects were administered the Children's Embedded Figures Test (CEFT) in order to assess field independence. There was a total of 64 subjects that were arrayed in the design as shown in Table 2.

Insert Table 2 about here

Results

The data analysis consisted of an multifactor ANOVA using a least squares solution to account for unequal n's. The dependent variable, Recognition, was scored in the following manner: 0 = No recognition of either figure, 1 = Recognition of the redesigned figure, 2 =

Recognition of the original figure, and 3 = Recognition of both figures.

The analysis of variance showed a significant main effect for the treatment variable $F(1,11)=40.27$, $p<.0001$. Subjects in Treatment II ($x=2.59$) recognized the figure more frequently than in Treatment I ($x=1.23$).

There were no significant differences for variables Grade and FI/FD cognitive styles, nor was there any interaction between or among variables.

Insert Table 3 about here

Discussion

As was expected, subjects were able to correctly name the main figure in the picture more often when presented the redesigned form or when presentation of the original picture followed the redesigned form as in the second trial. These results reiterate the need cited by Hochberg (1962:39) to enhance the edges of a figure so it is distinguishable. While figure enhancement has been determined to be important in traditional media, this study shows such figure enhancement to be at least as important with computer generated graphics. Furthermore, the nearly unanimous recognition of the original unicorn after experiencing the redesigned picture supports previous findings that experience and practice increase the ability to extract visual information (Gibson, 1969:77).

The lack of effect from field independence/field dependence may be explained by the notion that this particular type of cognitive style does not take precedence over perceptual development. Cognitive styles remain relatively stable over time and tasks (Ausburn & Ausburn, 1978). On the other hand, the ability to extract visual information improves with experience and maturation. The lack of effect from grade level would seem to negate developmental influence upon picture comprehension. However, a frequency count of the number of times the original unicorn was recognized in Treatment I showed a steadily increasing, yet statistically insignificant, pattern of recognition. Such results encourage a replication of the study with a larger sample that includes higher grade levels in addition to grades two, three, and four.

The data from this study have meaningful application to the design of instructional software that incorporates microcomputer generated graphics. The use of a picture as either a reward or as an exemplar is futile if the student cannot see what was intended to be seen. An earlier pilot study using the same pictures revealed that the redesigned unicorn had more appeal than the "horse", the label given to the original unicorn by the majority of the subjects. Additionally, if critical attributes are embedded in the picture, then that picture serves as a poor example. The student could possibly assimilate

erroneous information as well as miss critical informatin.

The producers of microcomputer generated graphics for computer courseware and educators who purchase the software have some evidence via this study that: 1) microcomputer generated graphics intended for color presentation but displayed on monochromatic monitors may not have sufficient figure/ground contrast, 2) insufficient figure/ground contrast may adversely affect picture comprehension, and 3) younger children, at least through fourth grade, seem to lack the necessary perceptual maturity to overcome the effects of poorly discernible figures on a monochromatic green screen. Since producers have no control over the display devices used with software, attention to the solutions for generating graphics for both color and monochrome display would lead to more intelligible pictures for children regardless of the type of monitor used.

Several elements of the study warrant further investigation. If the sample were larger and expanded to include kindergarten through sixth grade, would the very young children not recognize the original unicorn even after they had seen the redesigned picture and would the older children be able to recognize the unicorn more often even when presented with the original picture? In other words, the practice provided by the redesigned unicorn may not be enough cue for the young children to prompt recognition, and the older children's perceptual maturity may be advanced enough that they would not need the exposure of the redesigned picture to recognize the original one. Another question involves the lack of interaction between recognition and cognitive style. Is the inability of field independent subjects to overcome embeddedness a matter of perceptual immaturity as previously discussed or is it perhaps a function of the characteristics of the pictures used? A larger sample may again provide additional clues as would trying different pictures.

Other questions are prompted by the results of the study and deserve consideration by researchers who want to examine the properties of visual perception via computer generated graphics. Some of these questions include:

(1) What are the unique attributes of computer graphics display?
(2) How do these attributes compare to those of traditional media in terms of viewer perception and cognition?
(3) Do the results of the color/black and white studies hold true for computer generated pictures?

The purpose of this study was to investigate the comprehensibility of microcomputer generated color graphics that are displayed on monochromatic monitors. Such comprehensibility appears to be enhanced by attending to the arrangement of elements in the pictures so that figure/ground separation is apparent in either color or monochrome. Regardless of display hardware, pictures included in courseware can be designed to be comprehensible by users, especially young children.

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TABLE 1

Color Choice for Monochromatic Display Using Apple II Microcomputers

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Black	Magenta	Purple	Gray1*	Lt. Blue	White
	Dk. Blue	Md. Blue	Gray2	Pink	
	Dk. Green	Orange		Yellow	
	Brown	Lt. Green		Aqua	

*Gray1 and Gray2 are nearly indiscernible from each other, and are also very close in value to White. Caution should be used in juxtapositioning these three colors.

Note: From "Color Graphics and Monochromatic Display: Are They Compatible?" by P. Baker, 1983, Educational Technology, 22(12), p. 24. Copyright 1983 by Educational Technology Publications, Inc.

TABLE 2

Distribution of Subjects

		I	II*
Grade 2	FI	2	4
	FD	6	6
Grade 3	FI	8	5
	FD	4	8
Grade 4	FI	5	5
	FD	7	4
		n=32	n=32

*Order of graphic presentation

I = Original, redesigned

II = Redesigned, original

Note: From "Recognition of Computer-Generated Pictures on Monochromatic Monitors" by P. Baker, J. Belland, and M. Cambre, 1985, Journal of Computer-Based Instruction, 12(4), p. 105. Copyright 1985 by ADCIS.

TABLE 3

ANOVA of Figure Recognition by Treatment, Grade, and FI/FD Assessment

Source	df	SS	F
Treatment	1	27.5625	40.27*
Grade	2	0.1289	0.09
FI/FD	1	0.4017	0.59
T*G	2	0.4156	0.30
T*FI/FD	1	0.1436	0.21
G*FI/FD	2	0.6505	0.48
T*G*FI/FD	2	0.8601	0.63
Total:	11		

*p<.0001

Note: From "Recognition of Computer-Generated Pictures on Monochromatic Monitors" by P. Baker, J. Belland, and M. Cambre, 1985, Journal of Computer-Based Instruction, 12(4), p. 106. Copyright 1985 by ADCIS.